FINAL REPORT re Contract No. 23216-6-6111/01-SZ

"Draft Standard for Photovoltaic Storage Batteries"

Prepared by F.J.Quail, MASc, P.Eng.

F.J.Quail and Associates
44 Bearbury Drive
Etobicoke, Ontario
M9C 2G9

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DRAFT STANDARD FOR PHOTOVOLTAIC STORAGE BATTERIES

RENEWABLE ENERGY BRANCH

PREPARED FOR:

Renewable Energy Branch
Energy, Mines and Resources Canada
Ottawa, Canada

DSS Contract File No!
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PREPARED BY:

F.J.Quail, MASc, P.Eng.
F.J.Quail and Associates
44 Bearbury Drive
Etobicoke, Ontario
M9C 2G9

SCIENTIFIC AUTHORITY:

S.M.Pnevmaticos
Director, Solar Energy Development Program
Energy, Mines & Resources Canada
460 O'Connor, 4th Floor
Ottawa, Canada
K1A 0E4

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A major contributor to the development and completion of this work was Mr. D.J.Adkinson of Adkinson and Associates, 415 Brian Court, Pickering, Ontario L1W 3H5

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Quail, F.J., F.J.Quail and Associates

Draft Standard for Photovoltaic Storage Batteries

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Preface

A description is given of a procedure to be used by the designer of photovoltaic power generating systems to describe the characteristics of his PVG system which bear on the proper selection of electrical storage batteries. In addition, a procedure is outlined for a battery manufacturer to use in responding to the detail of the storage battery function and requirements, as described by the designer.

The draft standard is intended to serve as a means of communication between the PVGS designer and the manufacturer of storage batteries. This means of communication has been lacking, leaving the selection of storage batteries mostly in the hands of the manufacturer.

Abstract

The draft standard is the result of the need to supply the PV systems designer with guidelines for use in defining his storage battery requirements, and for the manufacturer of batteries a response mechanism which matches the defined performance needs of the designer.

Any reference to specific battery types such as lead-acid, or Ni-Cd, has been avoided except in some of the testing. Hence the document is adaptable to the peculiarities of any of the variety of storage batteries now available or being developed.

A system of classification of the level of precision of the data relating to batteries is provided as a means of ensuring that the data on characteristics of batteries and the rationale behind the source of information is understood.

Objectives

The continuous operation of Photovoltaic Systems depends on irradiation from the sun in the daytime and replaced by an auxillary energy system during nighttime or times when the sun is obscured. The auxillary source of energy is most commonly from storage batteries. In this mode, storage batteries are required to deliver energy and to be recharged, very often under conditions which are much beyond those experienced by batteries in normal use. In isolated use, for example, temperatures may range from +80C to -40C.

Because of the problems associated with the selection of appropriate storage batteries for PV Systems service, it is essential that appropriate test and acceptance criteria be developed, coupled with a guideline on selection based on anticipated service requirements.

This proposal entailed the development of a draft standard to be used as a basis for the development of a Canadian national standard through an accredited standards writing organization such as the Canadian Standards Association.

Work on PV storage standards on sizing and on installation is now underway through the Institute if Electric and Electronic Engineers in the United States and through the International Electrotechnical Commission in Europe. The approaches now being taken by both bodies will be of value but are not of a nature that will satisfy Canadian need. The Canadian document is of such a nature as to satisfy the needs of the systems designer and user, as well as those of the product manufacturer.

Executive Summary

The document "Standard for the Characteristics of Storage Batteries for Terrestrial Photovoltaic Systems" describes a method of presenting technical data which relates to the selection of storage batteries for photovoltaic systems, and to the accuracy of the information. Two perspectives are considered, namely, that of the PV systems designer and that of the manufacturer of storage batteries. The document is a means of reconciling the needs of the designer with the capability of the battery manufacturer.

The precision of the data is defined in terms of a grading system, where a Grade A designation applies to a storage battery designed and constructed specifically to the needs of the PV system, and tested by an outside agency. Grade E data is data based purely on analagous and/or theoretical considerations, and represents the other end of the scale.

A substantial list of words and definitions unique to the PV storage technology is included. References are included as well.

A standardized method of presenting data is outlined for use by the systems designer and by the storage battery manufacturer. Its purpose is to ensure that both the designer and the manufacturer understand the needs on the one hand and the capabilities on the other, in terms that are clearly spelled out.

A series of methods of tests for storage batteries are included for those situations where there is a need to verify performance by actual testing.

The document outlines what is to be included in the storage battery manufacturer's manual and establishes his labelling requirements as well.

The work of this document was accomplished by consultation with the published literature and by reference to the experiences of the PV systems designer and the producer of batteries.

Results

This work has resulted in the development of a draft standard (attached) on the characteristics of storage batteries for terrestrial photovoltaic systems. It is proposed that a Canadian Standards Association Technical Committee be established to proceed with the development of a formal Canadian standard on this topic. To this end, and as a part of the full development of this proposal, a CSA Technical Committee is being established. A proposed membership list is appended. Not all these persons have been confirmed as members as of this date (March 24, 1987). A solicitation for comments on the draft in its second stage of development was made to persons known to be familiar with this technology. At the same time, a request was made that the responder indicate a possible willingness to serve on the CSA committee.

STANDARD FOR THE CHARACTERIZATION OF STORAGE BATTERIES FOR TERRESTRIAL PHOTOVOLTAIC SYSTEMS

Note: This is not an adopted standard but is a draft issued for critical review and comment only.

Third draft
March 1987

PREFACE

This is the first edition of a preliminary standard on "Characterization of Storage Batteries for Terrestial Photovoltaic Systems". It is written in SI (metric units).

The first drafts were assembled by a small working group with support from Energy, Mines and Resources Canada during 1986 and 1987. In preparing this standard, the principal objective has been to establish a format for the presentation of information on storage batteries consistent with the needs of the PV systems designer, including his need to be aware of the limitation inherent in storage batteries. The standard is written in such a way as to not preclude the use of any specific type of battery. The IEEE is preparing documents on sizing of lead-acid batteries for PV application and also on installation and maintenance.

It is to be noted that the reliability of the system, not just the storage battery, is of major concern to the designer. While the performance of the storage battery is critical to the longevity and reliability of the system, nevertheless the designer must satisfy himself that all of the elements of his system will survive for the time required and at the level of performance required by the application.

F 382

STANDARD FOR CHARACTERIZATION OF STORAGE BATTERIES FOR TERRESTIAL PHOTOVOLTAIC SYSTEMS

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(F 382) STANDARD FOR THE CHARACTERIZATION OF STORAGE BATTERIES FOR TERRESTIAL PHOTOVOLTAIC SYSTEMS

Clause 1.0 SCOPE

1. This standard describes the method of presenting technical information relating to the selection of storage batteries for photovoltaic systems and to the precision of that information.

2. This standard prescribes methods of characterizing the quality of the data. Five classes of data shall be defined.

Class A - Real Experimental or test (hard) data based on specific testing of actual models of the battery under consideration under the specified conditions. [actual test]

Class B - Data derived from real experimental or test (hard) data on a specific model or type of battery but not on the identical size (e.g. differing in number or size of cells). [different unit tested]

Class C - data obtained by extrapolation to other conditions (ie temperature ,rate,etc) from known test data for specific batteries but not verified by additional testing. [same unit, different conditions]

Class D - Data obtained by extrapolation to different conditions of class B data. [different unit, diferent conditions]

Class E - Data based on analagous applications or theoretical considerations. [no test]

3. This standard does not consider the implication of storage battery systems with a nominal terminal voltage in excess of 130 volts.

4. This standard does not describe the characteristics of specific battery types such as lead acid or nickel

cadmium or others.

5. This standard does not cover installation or maintenance, nor does it deal with detailed sizing procedures or any mechanisms for interfacing with other components in the PV installation.

6. This standard does not deal with matters of testing for reliability and longevity of storage batteries. (Note: This paragraph 6 to be removed if Clause 6 on testing remains in).

Clause 2.0 REFERENCED DOCUMENTS

(later)

Clause 3.0 DEFINITIONS

Active Material - The constituents of a cell that participate in the electrochemical charge/discharge reaction.

Activation Polarization - Polarization resulting from the rate determining step of the electrode reaction (see also polarization).

Ampere-Hour Efficiency - See Efficiency.

Anode - The electrode in an electrochemical cell at which chemical oxidation takes place. During charge, the positive terminal of the cell is the anode. During electric discharge, the situation reverses and the negative terminal of the cell is the anode. However, battery manufacturers normally refer to the negative terminal as the anode during both charge and discharge (see also cathode).

Autonomy - The period of time during which a fully charged battery can satisfy the load with no contribution from the photovoltaic array or auxilliary power source; usually defined in terms of a number of days (24-hour periods).

Available Capacity - See Capacity.

Battery - Two or more electrochemical cells electrically interconnected in an appropriate series/parallel arrangement to provide the required operating voltage and current levels. Under common usage, the term battery also applies to a single cell if it constitutes the entire electrochemical storage system.

Capacity (C) - Generally, the total number of ampere-hours that can be withdrawn from a fully charged cell or battery at a specified discharge current, temperature and cut off voltage.

o Rated Capacity - The manufacturer's estimate of the minimum number of ampere-hours that can be withdrawn

from a new cell or battery for a specified discharge rate, temperature and cutoff voltage.

o Installed Capacity - The total number of ampere-hours that can be withdrawn from a new cell or battery when discharged to the system specificed cutoff voltage at the system design rate and temperature (i.e., discharge to the system design specifird maximum depth of discharge

o Available Capacity - the total number of ampere-hours that can be withdrawn from a cell or battery for an actual specific set of operating conditions including discharge rate, temperature, initial state of charge. age and cut off voltage.

o Energy Capacity - The total number of watt-hours (kilowatt-hours) that can be withdrawn from a fully charged cell or battery. The energy capacity of a given cell varies with temperature, rate, age and cutoff voltage. This term is more common to system designers than it is to the battery industry where capacity usually refers to ampere-hours. The watt hour capacity is nominally equal to the amp hour capacity times the nominal voltage.

Cathode - The electrode in an electrochemical cell at which electrochemical reduction takes place. During charge, the negative terminal of the cell is the cathode. During discharge, the situation reverses and the positive terminal of the cell is the cathode. However, battery manufacturers normally refer to the positive terminal as the cathode during both discharge and charge (see also anode).

Cell - The basic electrochemical unit used to store electrical energy consisting of an assembly comprising electrodes, elctrolyte and possibly separators.

Charge Rate - The current applied to a cell or battery to restore its available capacity. This rate is commonly normalized with respect to the rated capacity of the cell or battery. For example, the 10 hour charge rate of a 500 ampere-hour cell or battery rated at the 10 hour rate is C/10.

Rated Capacity / Charge Time = 500 ampere-hours / 10 hours = 50 amperes=C/10 rate

Unforunately, the ampere hour efficiency of all secondary batteries is less than 100 percent. Therefore, the time required to completely recharge a cell from 100 per cent depth of discharge is often longer than indicated by the so called "hour rate".

Charging - Conversion of electrical energy into chemical potential energy within a cell by the passage of a direct current in the direction opposite to that of discharge.

Closed Circuit Voltage - the potential or voltage of a cell or battery when it is discharging.

Co-efficient of Use - The percentage of total active material contained within a cell that is converted during the discharge of 100 percent of rated capacity (also called utilization factor).

Concentration Polarization - Polarization caused by the depletion or enrichment of ions in the electrolyte at the surface of the electrode (see also polarization).

Cutoff Voltage (Final Voltage) The cell or battery voltage at which discharge is terminated. Cut off voltage is specified by the cell manufacturer and is generally a function of discharge rate. Discharge beyond the specified cutoff voltage usually results in increasingly rapid decreases in cell voltage and energy output, may permanently damage the cell and may void a manufacturer's warrantee.

Cycle - One discharge-charge sequence to a specified depth of discharge.

Cycle Life - The number of cycles, to a specified depth of discharge, under specified conditions that a cell or battery can undergo before failing to meet its specified capacity or efficiency performance criteria.

Cycle Service - A duty cycle characterized by frequent and usually deep discharge-charge sequences, such as motive power applications.

Deep Discharge - Withdrawal of a significant percentage of rated capacity (50 percent or more).

Depth of Discharge (DOD) - The ampere-hours removed from a fully charged cell or battery, expressed as a percentage of rated capacity. For example, the removal of 25 ampere-hours from a fully charged 100 ampere-hours rated cell results in a 25 percent depth of discharge. Under certain conditions, such as discharge rates lower than that used to rate the cell, depth of discharge can exceed 100 percent.

Discharge - The process of withdrawing current from a cell or battery by the conversion of chemical energy into electrical energy.

Discharge Rate (a) The current removed from a cell or battery. This rate can be expressed in amperes, but more commonly it is normalized to rated capacity (C), and expressed as C/X.

For example, drawing 20 amperes from a cell with a rated capacity of 100 ampere-hours is referred to as the C/5 discharge rate (100 Ah/20A). Similarly, discharge currents of 5, 10 and 33.3 amperes would be designated as the C/20, C/10 and C/3 rates, respectively (see also hour rate).

Discharge Rate (b) (Equivalent or Functional Hour Rate) - This hour rate is determined by dividing the final capacity including the design margin, by the maximum current drawn (peak coincident current).

Duty Cycle - The operating regime of a cell or battery including factors such as charge and discharge rates, depth of discharge, cycle length and length of time in the standby mode.

Efficiency - The ratio of the useful output to the input:

- Ampere-Hour (Coulombic) Efficiency - The ratio of the ampere-hours removed from a cell or battery during a discharge to the ampere-hours required to restore the initial capacity:

$$\frac{\text{ampere-hours discharge}}{\text{ampere-hours of charge}} = \frac{\int_0^t i_d \, dt}{\int_0^t i_c \, dt}$$

where id and ic are the constant current discharging and charging currents, respectively, and td and tc are the discharging and charging times, respectively.

- Voltage Efficiency - The ratio of the average discharge voltage of a cell or battery to the average charge voltage during the subsequent restoration of an equivalent capacity.

- Energy (Watt-hours) Efficiency - The ratio of the energy delivered by a cell or battery during a discharge to the total energy required to restore the initial state of charge. The watt-hour efficiency is approximately equal to the product of the voltage and ampere-hour efficiencies. This is sometimes referred to as the roundtrip efficiency. Roundtrip energy efficiencies usually do not include energy losses resulting from self-discharge, auxiliary equipment (parasitic losses) or battery equalization.

Electrolyte - The medium which provides the ionic transport mechanism between the positive and negative electrodes of a cell. In some cells, such as the lead-acid type, the electrolyte may also participate directly in electrochemical charge/discharge reactions.

End-of-Charge-Voltage - The cell or battery voltage at which the finishing charge is normally terminated by the charging source.

Energy Capacity - See Capacity.

Energy Density - The ratio of rated energy available from a cell or battery, normalized to its weight or volume.

Equalization - The process of restoring all cells in a battery to an equal state-of-charge. For lead-acid batteries this is a charging process designed to bring all cells to 100 percent state-of-charge. Some battery types may require a complete discharge as a part of the equalization process.

Equalizing Charge - A continuation of normal battery charging, at a voltage level slightly higher than the

normal end-of-charge voltage, in order to provide cell equalization within a battery.

Equivalent Rate - See Discharge Rate.

Final Voltage (FV) - See Cutoff Voltage.

Finishing Charge Rate - The rate specified for charging a cell or battery that is nearing 100 percent state-of-charge.

Float Service - A duty cycle characterized by long periods of standy operation, at full charge and permanently connected to a constant voltage charging source with only occasional discharge/charge sequences.

Formation - The process, during manufacture or installation, by which the electrode materials are transformed into the compositions required for cell operation. For example, the active materials of a fully charged lead-acid cell are lead for the negative and lead dioxide for the positive plates. However, both plates are manufactured using lead oxide. During specially designed charging cycle, the lead on the negative plates is reduced and the lead on the positive plates is oxidized, thereby forming the active materials.

Functional Rate - See Discharge Rate.

Functional Load - Load that would be supported by the system throughout the autonomous period by a continuous discharge current at the functional rate.

Gassing - The production of gas from one or more of the electrodes in a cell. Gassing commonly results from the electrolysis of water in the electrolyte during charging.

Grid - An electrically conductive structure that supports the active material of a plate but should not electro chemically participate in the normal charge/discharge reaction.

Hour Rate - The discharge rate of a cell or battery expressed in terms of the length of time a new, fully charged cell or battery can be discharged at a specific current before reaching a specified cutoff voltage:

hour-rate = C/i

where C is the rated capacity of the cell or battery and i is the specified discharge current. For example, if a new, fully charged cell rated at 100 ampere-hours can be discharged at 20 amperes for a period of 5 hours before reaching the cutoff voltage, discharge of the battery at 20 amperes is referred to as the 5 hour rate (C/i = 100Ah/20A).

Unfortunately, for most cells, available capacity is not constant with discharge rate. Therefore discharge current cannot always be calculated by dividing discharge time into rated capacity. For example, a lead-acid battery with a rated capacity of 100 ampere-hours at the 5-hour rate may only deliver 88 ampere-hours at the 3-hour rate before reaching the cutoff voltage. The discharge current at the 3-hour rate would therefore be 29.3 amperes rather than 33 amperes as might otherwise be expected and would be designated as the C/3.4 rate (see also discharge rate).

Hours of Capacity - The total number of hours for which a fully charged cell or battery is capable of supplying the system load demand before reching the specified maximum depth of discharge.

Installed Capacity - See Capacity.

Life - The period during which a cell or battery is capable of operating above a specified capacity or efficiency performance level. For example, with lead-acid batteries, end-of-life is generally taken as the point in time when a fully charged cell can only deliver 80 percent of its rated capacity. Depending on the application this % figure may be specified differently. Beyond this state of aging, deterioration and loss of capacity begins to accelerate rapidly. Life may be measured in cycles and/or years, depending on the type of service for which the cell or battery is intended.

Local Action - Chemical reactions within a cell that convert the active materials to a discharged state without supplying useful energy through the battery terminals (self-discharge).

Maintenance-Free Battery - A cell or battery in which it is not intended that the user have access to the electrolyte. This also includes batteries known as sealed batteries.

Motive Power Cell or Battery - A cell or battery that is intended to power electrically operated mobile equipment (fork lift trucks) and is designed to be operated in a daily deep cycle regime at moderate (C/6) discharge rates.

Nominal Operating Voltage - The average terminal voltage of a cell or battery discharging at a specified rate and at a specified temperature.

Nominal Reserve Capacity (In Time) - The nominal reserve capacity An is specified by the manufacturer. It is a period during which a battery can supply a fixed current Ii down to a specified end Voltage.

No Sun

(1) Number of equivalent consecutive days during which there is no array output due to weather conditions. This information is derived from local weather date.

(2) A "no sun" day is any day when the array output is insufficient to supply the system load and maintain the battery's charge.

Note: Partial "no sun" days should not be combined to produce a "no sun" day.

Open Circuit Voltage - The terminal voltage of a cell or battery at a specified state-of-charge and temperature when the circuit is open (no load conditions).

Overcharge - The forcing of current through a cell after all of the active material has been converted to the charged state. In other words, charging continued after 100 percent state-of-charge is achieved. Overcharging does not increase the energy stored in a cell and usually results in gassing and/or excessive heat generation, both of which reduce battery life.

Pilot Cell - (To be defined)

Plate - An assembly of active material and, in some

cases, a support grid. The plates form the positive and negative electrodes of the cell.

Polarization - The deviation from open-circuit voltage caused by the flow of current in an electrochemical cell.

Power Density - The ratio of the rated power available from a cell or battery, normalized to its weight or volume.

Primary = Cell or Battery - A cell or battery whose initial capacity cannot be significantly restored by charging and is therefore limited to a single discharge.

Rated Capacity - See Capacity.

Reversal - Continued discharge of a cell to the point that the cell's electrical terminals change polarity.

Reversible Potential - The open-circuit (zero-current) potential of a reversible chemical reaction.

Secondary Battery or Cell - A battery or cell that is capable of being charged repeatedly.

Self-discharge - The process by which the available capacity of a cell is reduced by internal chemical reactions (local action).

Self-discharge Rate - The amount of capacity reduction occurring per unit of time in a cell as the result of self-discharge.

Separator - An electrically non-conductive and ionically permeable material used to prevent the direct contact of individual plates within a cell.

SLI Battery - Starting, lighting and ignition battery (standard automotive battery) designed primarily for high rate, low depth of discharge operation typical of automobile engine starting.

Stationary Cell or Battery - A cell or battery that is generally intended for float service, usually in a fixed location.

State-of-Charge (SOC) - The available capacity in a cell or battery expressed as a percentage of rated capacity.

For example, if 25 ampere-hours have been removed from a fully charged 100 ampere-hours cell, the new state-of-charge is 75 percent.

Storage Battery - see Secondary Battery (above)

Sulphation - The formation of lead-sulphate crystals on the plates of a lead-acid battery. Commonly used to designate the large crystals which form in partially discharged cells as the result of temperature cycling. These large crystals are more difficult to reduce by the charging current than are the smaller crystals that result from normal and self-discharge reactions. Sulphation can be caused by leaving the battery in a discharged state for long periods of time.

Traction - see Motive Power

Voltage Efficiency - see Efficiency

Voltage Temperature Compensation Factor - TBD

Utilization Factor - see Coefficient Use

Watt-hour Efficiency - see Efficiency

Clause 4.0 DATA CLASSIFICATION

Clause 4.1 QUALITY OF DATA

Class A-1

The experimental data obtained from testing on a specific battery model and is only applicable to conditions under which the battery was tested. The data supplied by an independent test laboratory.

Class A-2

As above for Grade A-1 but testing performed by the manufacturer in-house.

Class B

Data derived from real experimental or test (hard) data on a specific model or type of battery (Class A-1 or A-2) but not on the identical size (e.g. differing in number or size of cells). [different unit tested]

Class C

Data obtained by extrapolation to other conditions (ie temperature ,rate,etc) from known test data for specific batteries but not verified by additional testing. [same unit, different conditions]

Class D

Data obtained by extrapolation to different conditions of class B data. [different unit, diferent conditions]

Class E

Data based on analagous applications or theoretical considerations. [no test]

Clause 5.0 METHOD OF DATA PRESENTATION

This clause details the storage battery characteristic requirements involved in a proper system design originating from:

(A) By the Photovoltaic Power Generating (PVPG) Systems Designer

(B) By the Battery Manufacturer

5 .1 Data Presentation by the PVPG Systems Designer

5 .1.1 Detailed Load Profile - this should encompass an appropriate time period to include all representative loads. In addition to the average watt hours per day, peak loads, their frequency and their size relative to the average load are required in order to determine equivalent rate and functional load.

5 .1.2 System Configuration (Definition)

5 .1.2.1 Standalone - (SA) means a PGS or system that operates independently of the utility lines, also called "Utility Independent".

5 .1.2.2 Utility Interactive - Utility interactive (UI) means a PGS capable of operating in parallel with and supplying power to the utility line. The inverter will be commuted by the utility line.

5 .1.2.3 Standalone with On-site Auxiliary Backup -A standalone PV system with additional source(s) of electrical input power other than a utility grid connection.

5 .1.3 Capacity Requirements

5 .1.3.1 Shallow Discharge (not greater than 20% capacity on a daily basis nor more than 80% during use of autonomy storage (4 times a year))

5 .1.3.2 Deep Discharge (greater than 50% capacity on a daily basis)

5 .1.4 Reliability Requirements - eg. reserve capacity, accessibility, maintenance schedule, replacement philosophy

5 .1.5 Ambient Conditions

5 .1.6 Insolation Profile (automomy)

5 .1.7 Voltage Window (Voltage extreme that can safely be applied to load)

5 .1.8 Duty Cycle (battery)

5 .1.9 Safety and Environmental Concerns

5 .1.10 Budget Constraints

5 .2 Data Presentation by the Battery Manufacturer

5 .2.1 Capacity

5 .2.1.1 Ampere-hours at the prescribed temperatures at the specified hour rates (eg. 8, 24, 100, and 500 hours) for shallow or deep discharge as required by the design.

5 .2.2 Efficiency

- Ampere hour efficiency and watt hour efficiency at specified temperatures and loads.

Anticipated loss of efficiency attributed to repeated charge/discharge cycling, plus parasitic loss, plus over-charge loss effects.

5 .2.3 Voltage Range (under specified conditions)

5 .2.3.1 Recommended Cut-off Voltage or Discharge Limit

5 .2.3.2 Recommended End-of-charge Voltage in Volts Per Cell - Note - some loads (electronic equipment) may be damaged by normal end of charge voltages so the load voltage window should be checked closely.

5 .2.3.3 Recommended Over-charge Limits (for equalization)

5 .2.3.4 Recommended voltage to initiate recommended charge rate as a function of temperature (Voltage Temperature Compensation Factor)

5 .2.4 Charge/Discharge Rates

5 .2.4.1 Recommended Charge/discharge Rates In Amperes as a Function of Voltage

5 .2.4.2 Self-discharge Rate on Standby as a Function of Temperature

5 .2.5 Specific Gravity (SG) of Electrolyte

5 .2.5.1 S.G. recommended for hot (greater than 32oC) normal (25oC) and Cool (0oC,-20oC, -40oC) ambient conditions, or a combination of these.

5 .2.5.2 S.G. at Full Charge
- S.G. at 100% discharge (500 hr.rate)

5 .2.5.3 Freezing Point of Electrolyte vs S.G.

5 .2.6 Dimensions and Weights - Net weight and as packed for
(a) domestic or
(b) export shipping

5 .2.7 Options - e.g. hydrogen recombiner; enclosures; interconnects; circulation of electrolyte

5 .2.8 Maintenance Recommendations

5 .2.9 Battery Conditioning and Cell Equalization

5 .2.10 Polarity

5 .2.11 Shipping Options/Limitations
- Wet and Sealed
- Charged and Dumped
- Dry Charged

Clause 6.0 METHODS OF TEST

Note (1)

The tests for capacity and efficiency as noted here represent the current practice and are subject to continuing re-examination as more information is accumulated on how these tests are best conducted.

If manufacturers' tests procedure are not in accordance with the test as prescribed under this section, the manufacturer shall provide written detailed procedures for his tests as conducted.

Note (2)

The IEC definition (IEC Document No.) of a fully-charged battery is as follows:

A battery is considered as being fully charged when, at a charging current of 0.02 amps the voltage across its terminals and the specific gravity of the electrolyte do not vary appreciably during two consecutive hours at the end of the charging period, account being taken of temperature variations. During this charge, the electrolyte temperature shall be maintained between 15oC and 35oC, measured in one of the central cells.

The specific gravity and level of the electrolyte shall be made up to the values specified by the manufacturer when the cells bubble and the voltage is stabilized.

Note 3

The following tests are specified to be conducted at 25oC however, the operational temperature of the battery application may differ considerably from 25oC with markedly different results. For this reason, the tests may be conducted at other specified temperatures at the client's option.

Clause 6.1 CAPACITY AND ROUND-TRIP EFFICIENCY TEST

6.1.1 General

6.1.1.1

The voltage Window (Vmin the final discharge and Vmax the final charge voltage) shall be specified. The equalizing voltage V shall also be specified.

6.1.1.2

Charge and discharge rates - shall be specified and may be constant current or constant power.

6.1.1.3

Temperature of electrolyte - the temperature of the electrolyte shall be 27c - 30c at the start of the first discharge cycle and 34c - 46c during the charge cycle, or as otherwise specified. The temperature during each discharge/charge cycle shall be noted.

Clause 6.1.2 PROCEDURE

6.1.2.1

Before the test commences the battery must be fully charged (C6 note (2)) and all cells equalized. The level of the electrolyte in the battery must be as specified by the manufacturer and the S.G. as agreed to by the manufacturer and the system designer.

Both the electrolyte level and S.G. must be checked for uniformity (within +/- 0.050 SG Units) within each cell of the battery unit before testing is started.

All voltage, electrolyte temperature and charge/discharge rates must be measured.

6.1.2.2

(1) Discharge the fully charged battery using a schematic as illustrated in Figure (1) at the specified rate,

until the battery terminal voltage equals Vmin.

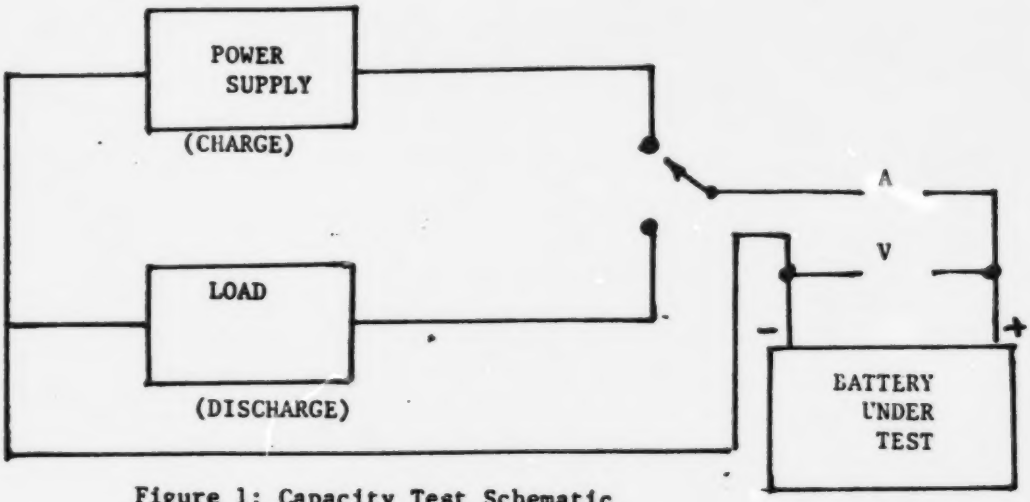

Figure 1: Capacity Test Schematic

Record cell and battery voltages at regular intervals

(2) Fully charge the battery at the specified rate to the final charge voltage V max

(3) Record the time to fully charge the battery (tc)

(4) If necessary, repeat steps (1) and (2) recording cell and battery voltages.

(5) Record the time (td) to discharge the battery to its final discharge voltage (V min)

(6) Calculate the battery ampere-hour capacity (Qd) where

Qd = average discharge rate amperes x time

and

Qc = average charge rate amperes x time

(7) Battery round-trip efficiency. nq is the ratio of ampere-hours removed to the restored

Note: If the battery temperature differs from 25oC temperature correction factor must be applied. This factor is to be supplied by the manufacturer.

Clause 6.2 CYCLING TESTS

6.2.1 Preparation

6.2.1.1

All tests shall be conducted at 25 - 28oC

6.2.1.2

Electrolyte level and S.G. of each cell shall be within manufacturer's tolerance.

6.2.1.3

Battery weight before and after testing shall be recorded. Weight change after each cycle shall be recorded.

6.2.1.4

Prior to testing the batteries shall be fully charged according to the manufacturer's specifications. The initial capacity shall be determined by the procedure given in Clause 6.2.3. Prior to the cycling tests, two or more capacity tests shall be run to provide baseline data.

6.2.1.5

In order to ensure that all cells are fully charged, an equalization charge as recommended by the manufacturer may be given every 4 weeks during the test period.

6.2.1.6

If facilities permit, the current battery voltage, cell voltage and battery temperature shall be monitored. Changes in any of these of more than 5% shall be recorded. Ampere-hours and watt-hours removed or returned shall be computed every minute and recorded with the above data. In particular, the voltages at the end of discharge and charge in addition to the current during the cycle (s) shall be noted.

6.2.2 TEST PROCEDURE

6.2.2.1 Shallow-discharge Cycle Test

Test (A) Standard Test

(i) The battery is discharged at a constant current corresponding to the C/20 rate for two hours removing 10 percent of the rated capacity; C, in this case, is the rated capacity at the 20h rate and 25oC. It is then charged for two hours at a constant voltage as recommended by the manufacturer, with the current limited to the C/10 rate, and the maximum input limited to 110 percent of the amp hours removed. This cycle is repeated with six cycles per day possible, as shown in Figure 2.

(ii) At intervals of no more than 100 cycles, two capacity tests are conducted as described in paragraph 6.2.3. If the battery capacity during the second discharge is greater than 80 percent of the rated Ah capacity, the battery is recharged and the cycle testing resumed.

Test (B) Partial State-of-Charge Test

(i) The battery is initially discharged at a constant current corresponding to the C/20 rate for the length of time necessary to reach the desired theoretical state-of-charge (e.g., 8 hours to reach 60% SOC). The battery may then be allowed to stand on open circuit before commencing the cycling regime.

(ii) A cycle consists of a two hour discharge followed by a two hour charge, both at a constant current of C/20. Thus, if the initial SOC was 60 percent, the battery is cycled between 50 percent and 60 percent, of the theoretical SOC, with the same amp-hours returned on charge as was removed on discharge. The cycle is repeated with six cycles per day possible, as shown in Figure 3.

(iii) At intervals of no more than 100 cycles, two capacity tests are conducted as described in paragraph 6.2.3. If the battery capacity during the second discharge is greater than 80 percent of the rated capacity, the battery is recharged and the cycle testing resumed.

6.2.2.2 Deep-Discharge Cycling Test

Test (A) Standard Test (Ref. NEMA 1B-3-1978)

(i) The battery is discharged for four hours at the C/5 rate, where C is the rated capacity at the 5h rate and 25oC. This results in an 80 percent DOD based on the battery's rated capacity. The battery is then charged following the manufacturer's rcommendations, but not to exceed 115% of the amp-hours removed. Total charge time shall not exceed eight hours. The cycle is then repeated with two cycles being completed per day as shown in Figure 4.

(ii) At intervals of no more than 50 cycles, two capacity tests are conducted as described in paragraph 6.2.3. If the battery capacity during the second discharge is greater than 80 percent of the rated capacity, the battery is recharged and the cycle testing resumed.

(iv) If the battery voltage drops below the specified end of discharge voltage during the test, that particular cycle shall be completed. If less than five cycles have been completed since the last capacity test, the battery shall be considered to have failed. Otherwise, two capacity tests shall be conducted per paragraph 6.2.3.

Test (B) Partial State-of-Charge Test

(i) The battery is initially discharged for one hour at the C/5 rate to remove 20 percent of the rated capacity. The battery may then be allowed to stand on open circuit before commencing the cycling regime.

(ii) A cycle consists of a three-hour discharge at the C/5 rate followed by a charge at the same rate returning an equivalent number of amp-hours. The recharge time is a nominal three hours, and the battery is being cycled between 20 percent and 80 percent of the nominal depth-of-discharge. The cycle is repeated with four cycles per day possible as shown in Figure 5.

(iii) At intervals of no more than 50 cycles, two capacity tests are conducted as described in paragraph 6.2.3. If the battery capacity during the second discharge is greater than 80 percent of the rated

capacity, the battery is recharged and the cycle testing resumed.

(iv) If the battery voltage drops below the specified end of discharge voltage during the test, that particular cycle shall be completed. If less than five cycles have been completed since the last capacity test, the battery shall be considered to have failed. Otherwise, two capacity tests shall be conducted per paragraph 6.2.3.

6.2.3 CAPACITY TEST (Ref. IB-2-1974)

(i)a. For Lead Acid Batteries
The shallow-discharge batteries shall be discharged at a constant current equal to the 20h rate at 25oC until the voltage reaches 1.75 volts times the number of cells. The deep-discharge batteries shall be discharged at a constant current equal to the 5h rate at 25oC until the voltage reaches 1.70 volts times the number of cells.

(i)b. For Nickel Cadmium Batteries (to be defined)
At the intervals indicated in the cycling tests above, the residual capacity is determined by discharging the battery at the appropriate rate until the specified cutoff voltage is reached. The battery is then recharged in accordance with the manufacturer's instructions.

(ii) The fully charged capacity is then determined by again discharging the battery at the appropriate rate to the specified voltage. The battery is again recharged as prescribed by the manufacturer.

(iii) The battery shall deliver a minimum of 80 percent of its rated capacity throughout its life, when tested in accordance with paragraph C above. If the battery fails to deliver the required capacity, an additional capacity test may be conducted for verification.

Clause 7.0 MANUFACTURERS' MANUALS

7.1

The manufacturer shall supply a manual which provides the information required in Clause 5 (B). Charts, graphs, or schematics are acceptable supplements to written detail.

Clause 8.0 LABELLING

8.1 (a)

The following information shall be permanently affixed to each battery location:

- Manufacturer's Name and Code Number
- Date and Location of Manufacture
- Number of Cells
- Nominal System Voltage
- Type and S.G. of Electrolyte @ 25oC

8.1 (b)

Each individual separately packaged cell or battery module shall be permanently marked with the folowing information:

- Model Number
- Polarity
- Nominal ampere-hour capacity @ 25oC at one given discharge rate to a specified cut-off voltage
- Electrolyte High and Low Level Marks

Appendix (A)

PROPOSED MEMBERSHIP LIST:

CSA F382 COMMITTEE ON PV STORAGE

R Coco
Marathon Standby Batteries
Leonard Electric Limited
1008 Rangeview Road
Mississauga, Ontario L5E 1H3

R Terzi
Environment Canada
Place Vincent Massey
351 St Joseph Blvd
Hull, Quebec K1A 0H7

Dr Brian Taylor
National Research Council
Chemistry Department
Montreal Road
Ottawa, Ontario K1A 0R6

Andre Belanger
Institut de Recherche de l'Hydro-Quebec
1800 Montee Ste-Julie
Varennes, Quebec J0L 2P0

Don Goulding
C.P.Rail
Office of the Chief Engineer
Room 405, Windsor Station
Montreal, Quebec H3C 3E4

Klaus Tamantschger
Astris Inc
2480 Donwin Drive
Mississauga, Ontario L5C 1J9

Larry Rolfe
Leonard Electric
1008 Rangeview Road
Mississauga, Ontario L5E 1H3

T Durack
Bell Canada
Bureau 18E2
700 Rue de la Gauchetaire Ouest
Montreal, Quebec H3B 4L1

....continued

Proposed list - CSA F382 (continued)

F.P.A.Odenkirchen
P and D Stationary Battery Service
P.O.Box 863
Waterdown, Ontario L0R 2H0

Ivor Nixon
Tele-Radio Systems
121 Hanlan Road
Woodbridge, Ontario L4L 3P5

Paul Olsen
Ontario Battery Services
50 Galaxy Road
Resdale, Ontario M9W 4Y5

Per Drewes
Ontario Hydro
700 University Avenue
Toronto, Ontario M5G 1X6

Don Adkinson
Adkinson and Associates
415 Brian Court
Pickering, Ontario L1W 3H5

S Bolcso
Energy, Mines and Resources Canada
Ottawa, Ontario

Brian Winkless
GNB Batteries (Canada) Inc
4500 Dixie Road
Cooksville, Ontario

Gary Hart
Batteries and Systems Inc

C.L.Gardner
Department of National Defence
Shirley Bay
Ottawa, Ontario K1A 0Z4

E.M.Valeriote
Cominco Product Research Centre
Sheridan Park
Mississauga, Ontario L5K 1B4